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(54) **FEDERATED MANAGEMENT OF
INTELLIGENT SERVICE MODULES**

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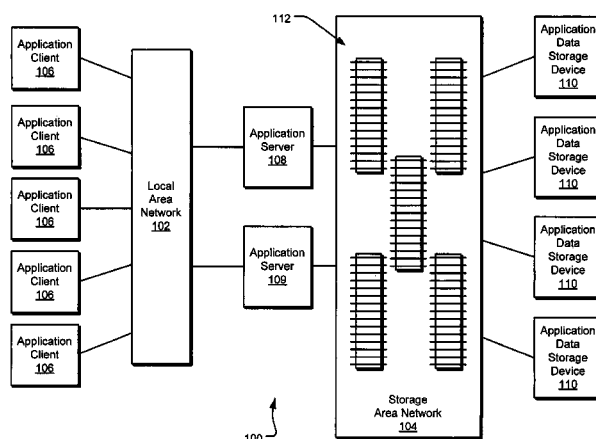
USPC 709/217–229, 203, 310; 370/466, 389,
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(57) **ABSTRACT**

Intelligent services are provided in a storage network using intelligent service modules that can be cabled to a switch external to the switch chassis and yet be managed as part of the switch's logical domain. Data and management communications between the intelligent service module and the core switch are provided through a “soft-backplane” implemented using in-band communications through cabling attached between the switch and the intelligent service module rather than through hardwired backplane within the chassis. Management communications from management software is directed to the switch, which handles the management functions relating to the intelligent service module or forwards the management requests to the intelligent service module for processing.

54 Claims, 9 Drawing Sheets



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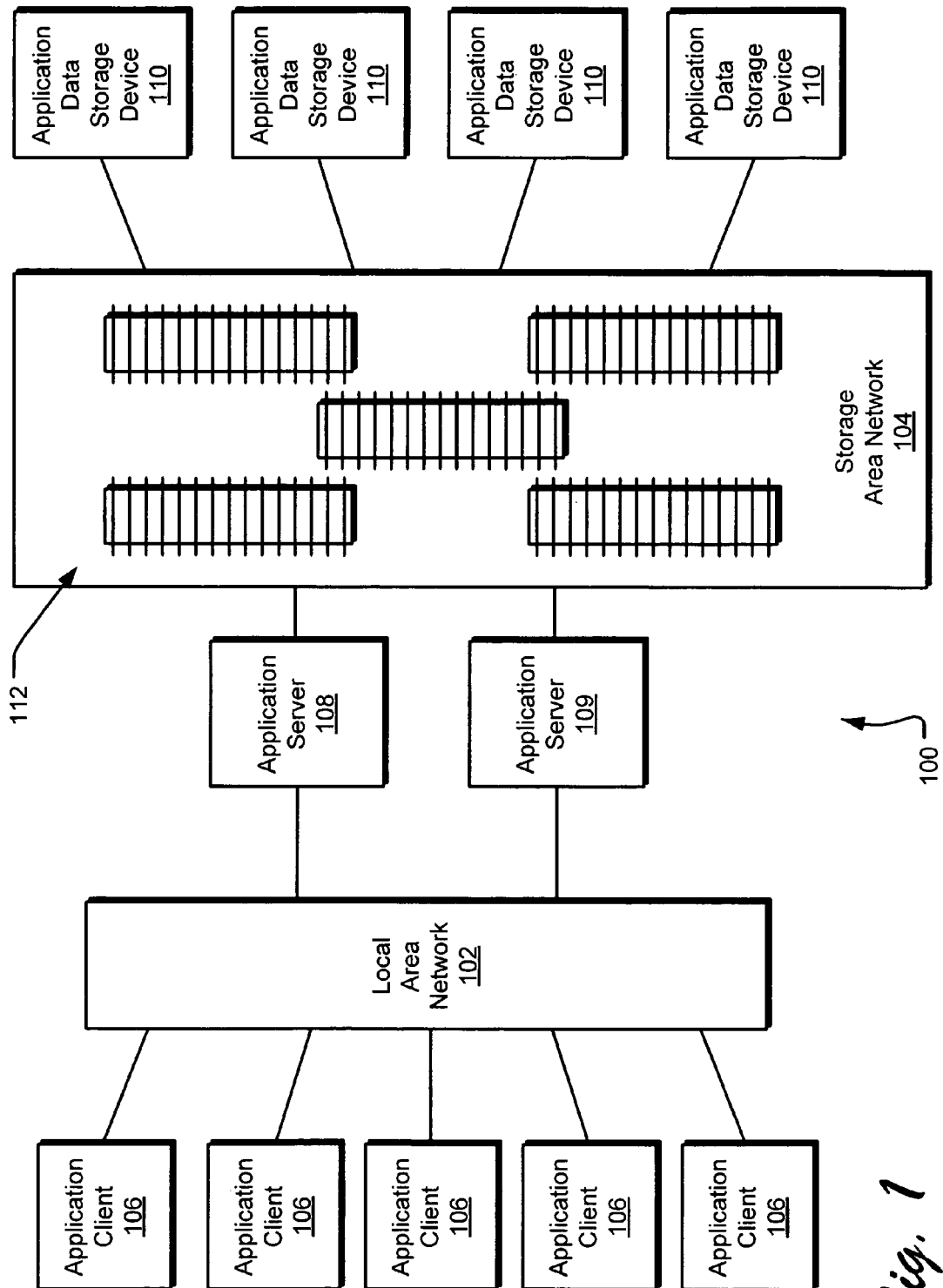


Fig. 1

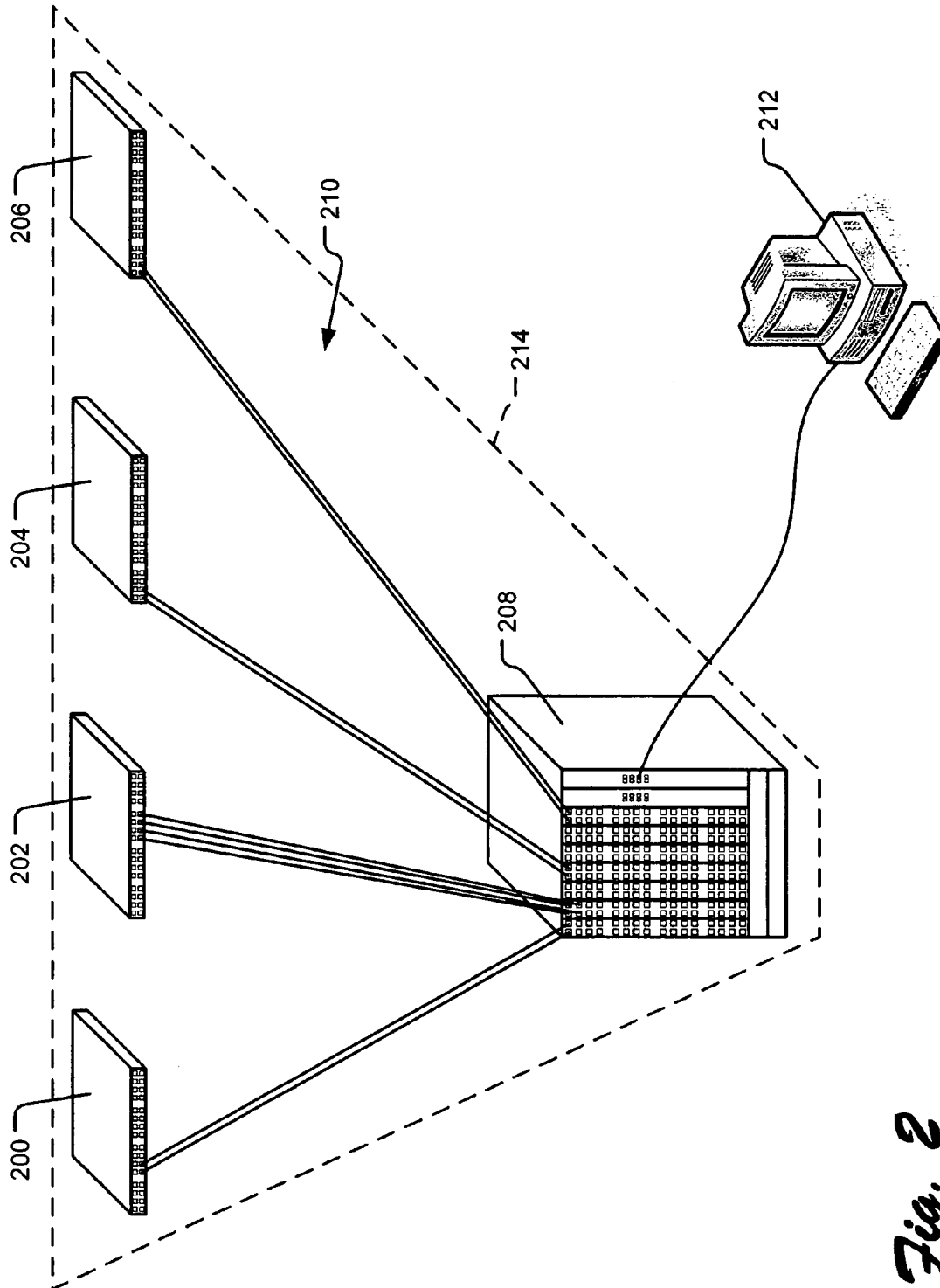


Fig. 2

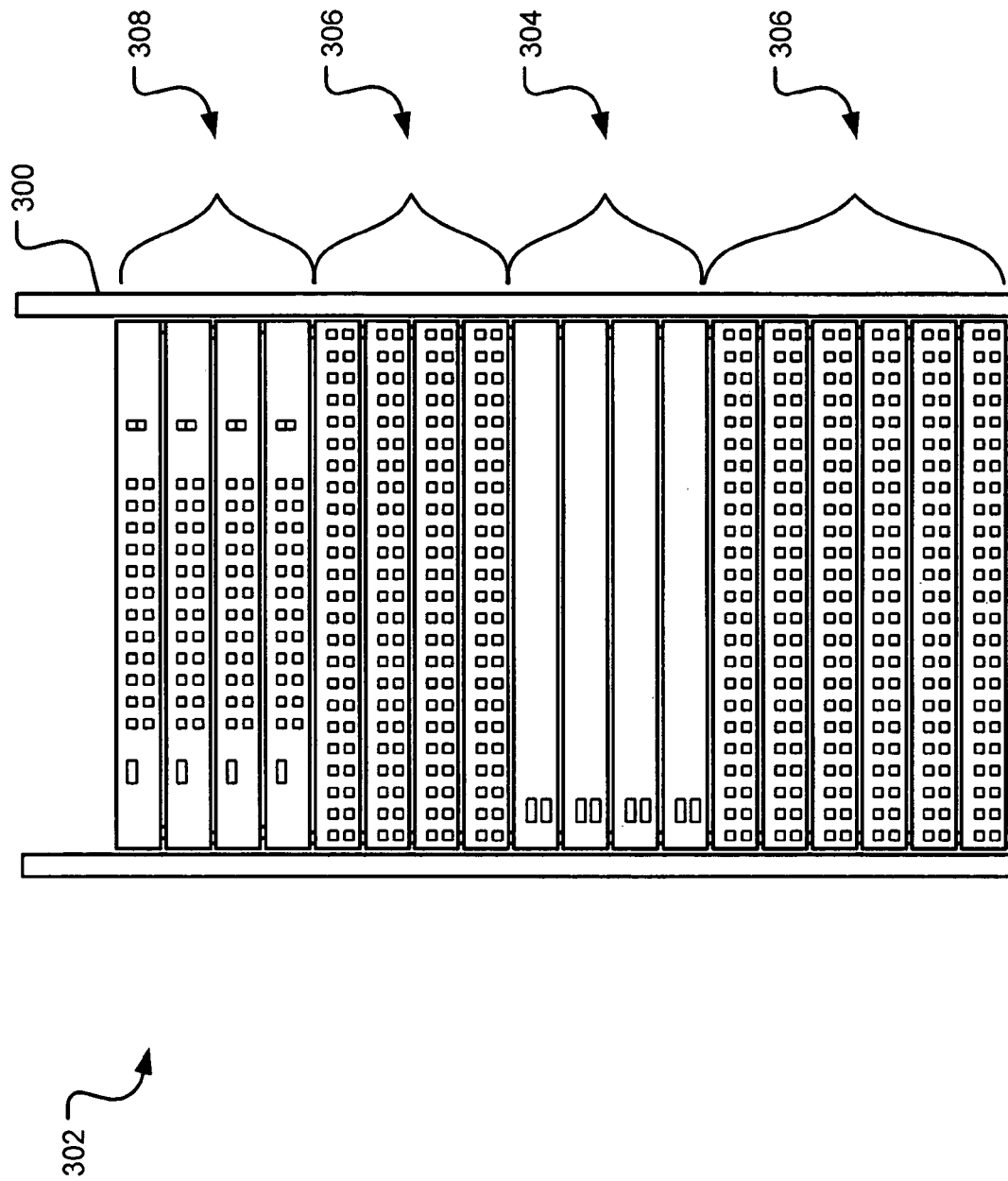


Fig. 3

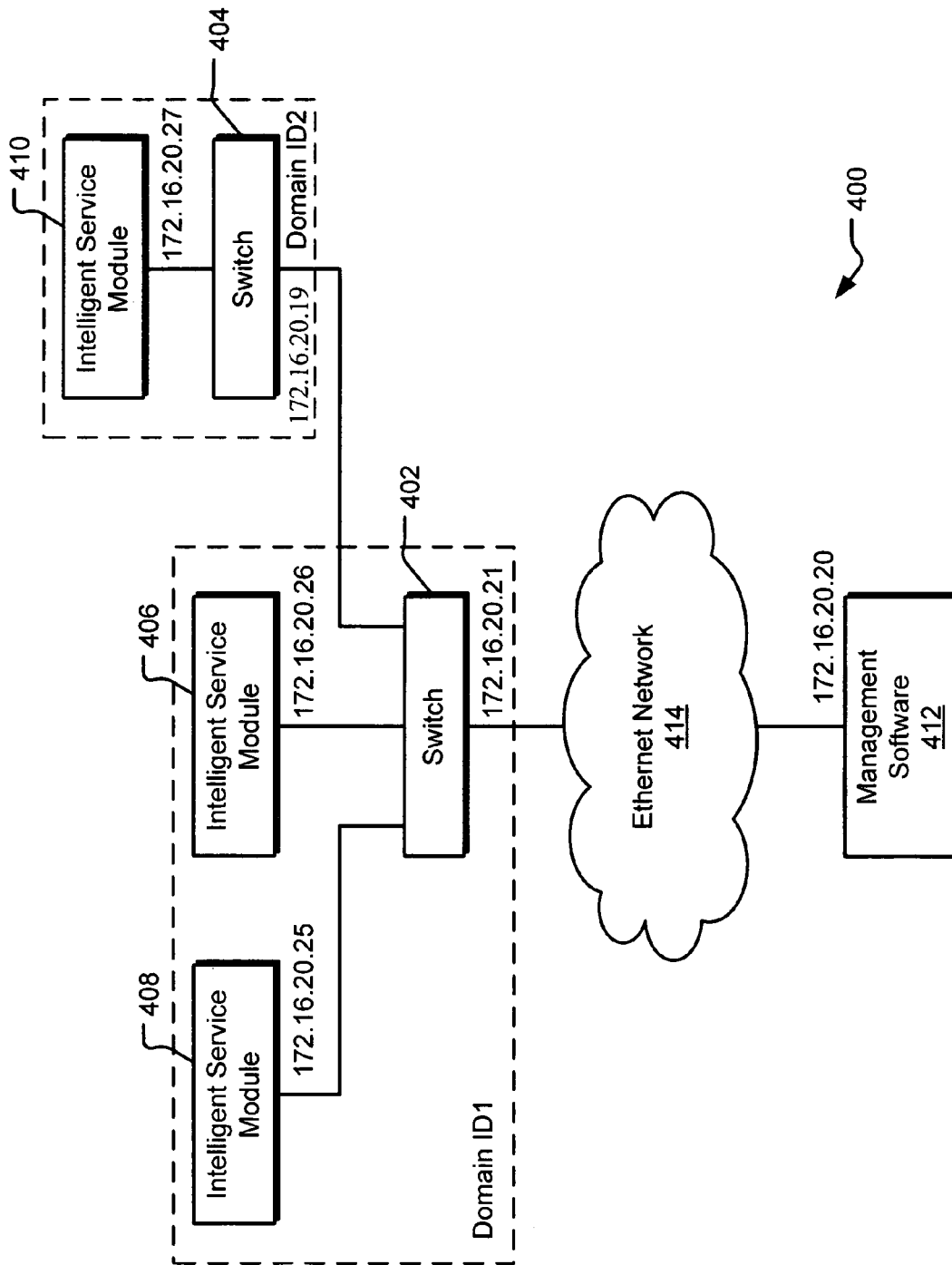
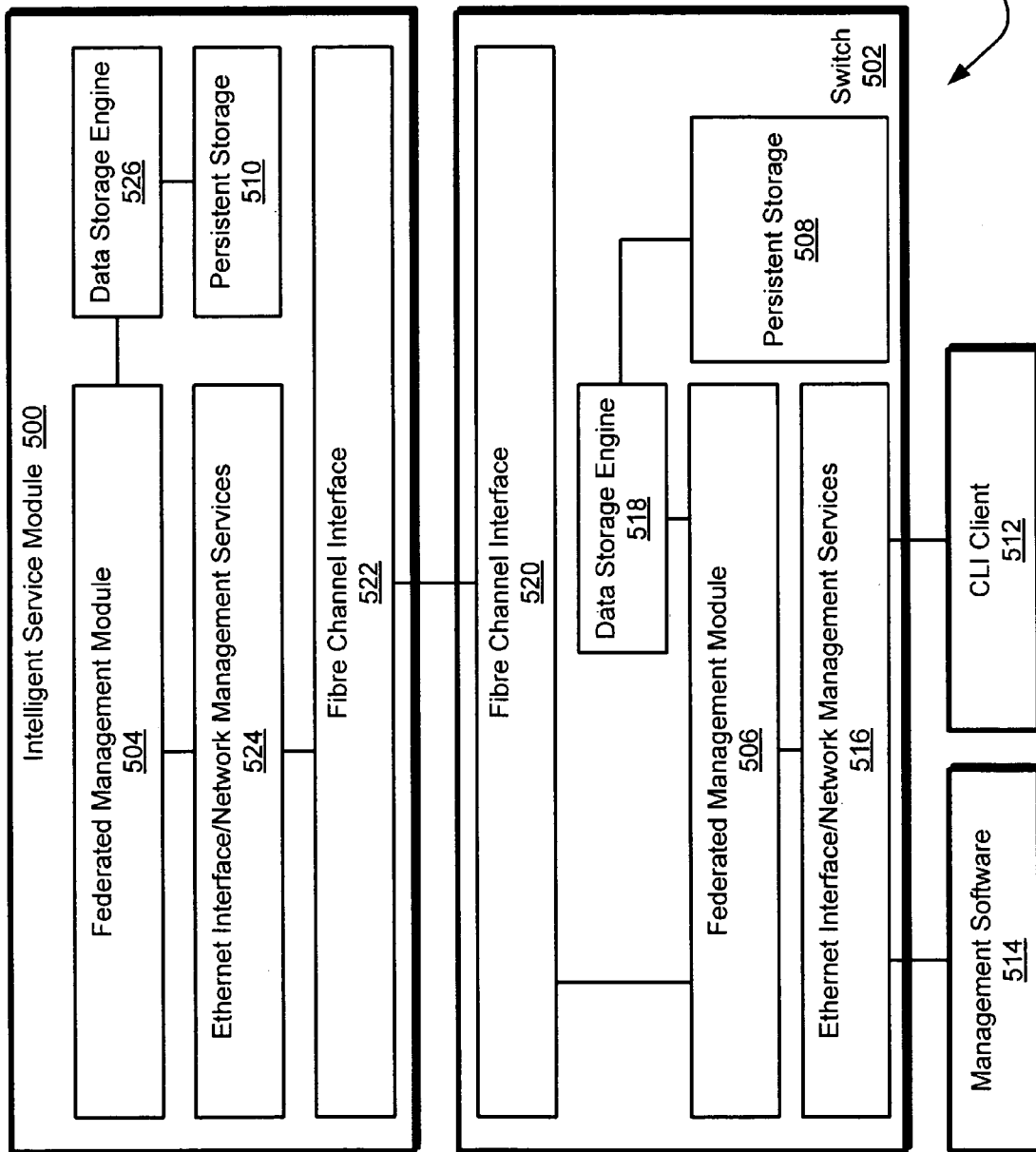
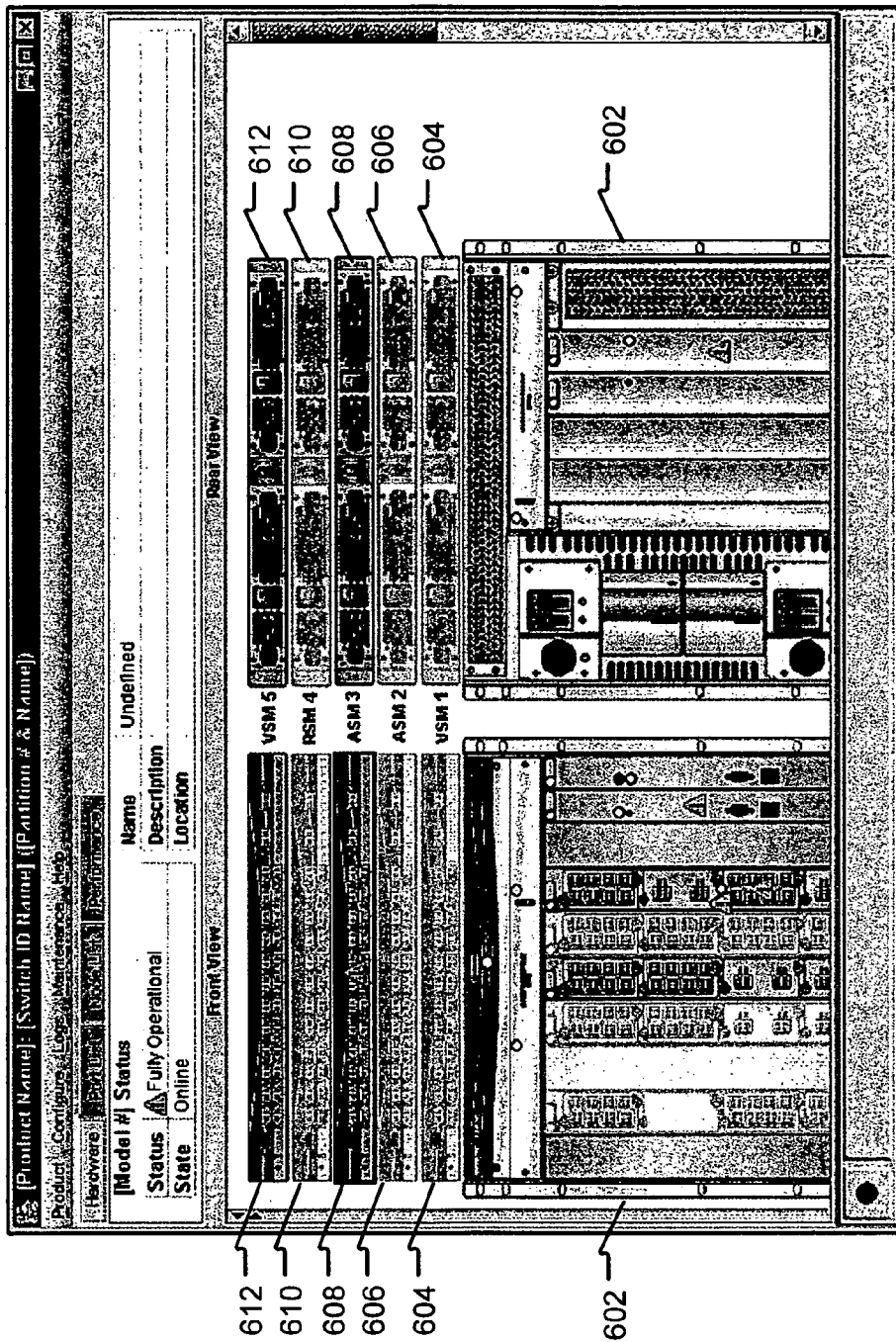


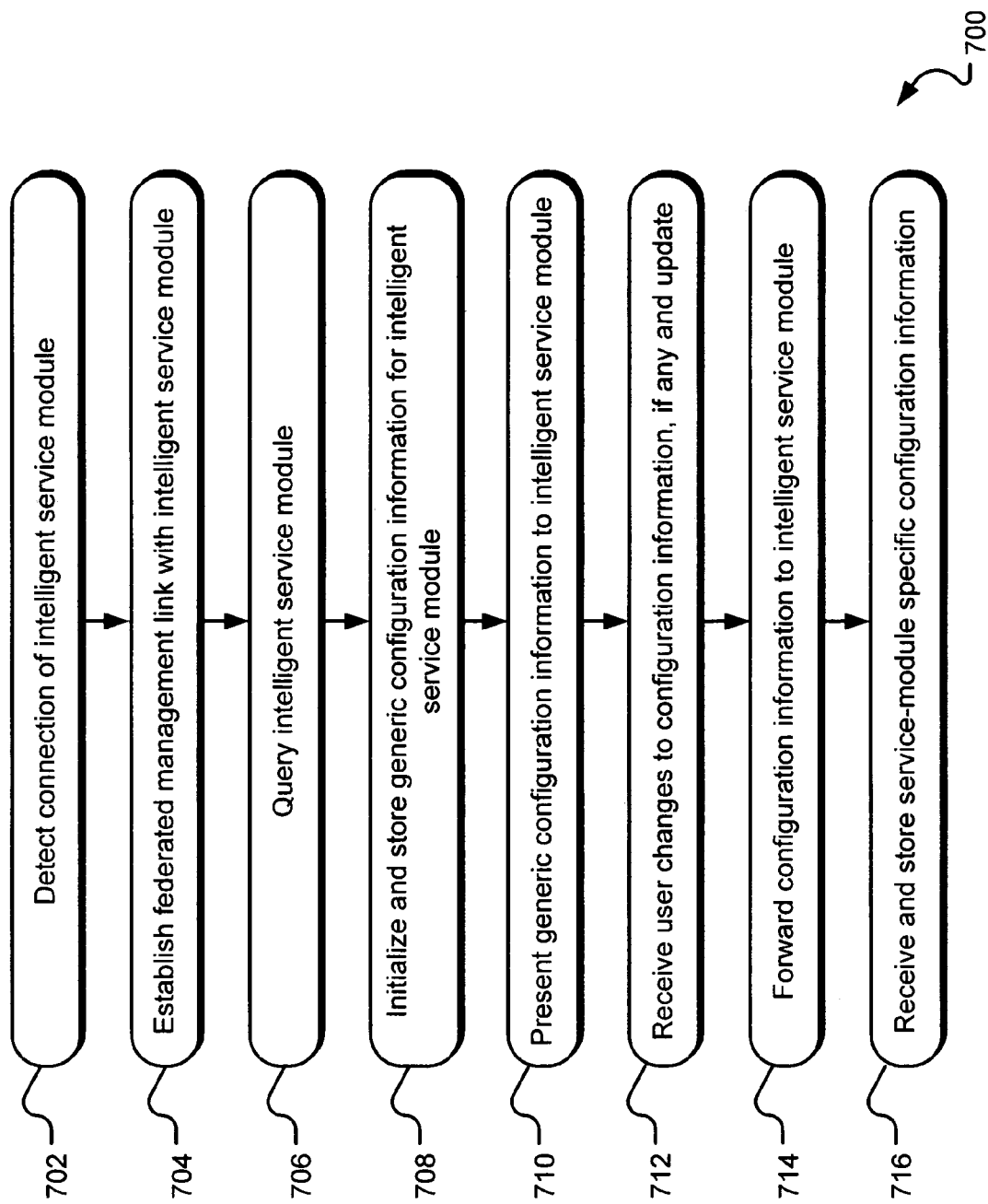
Fig. 4

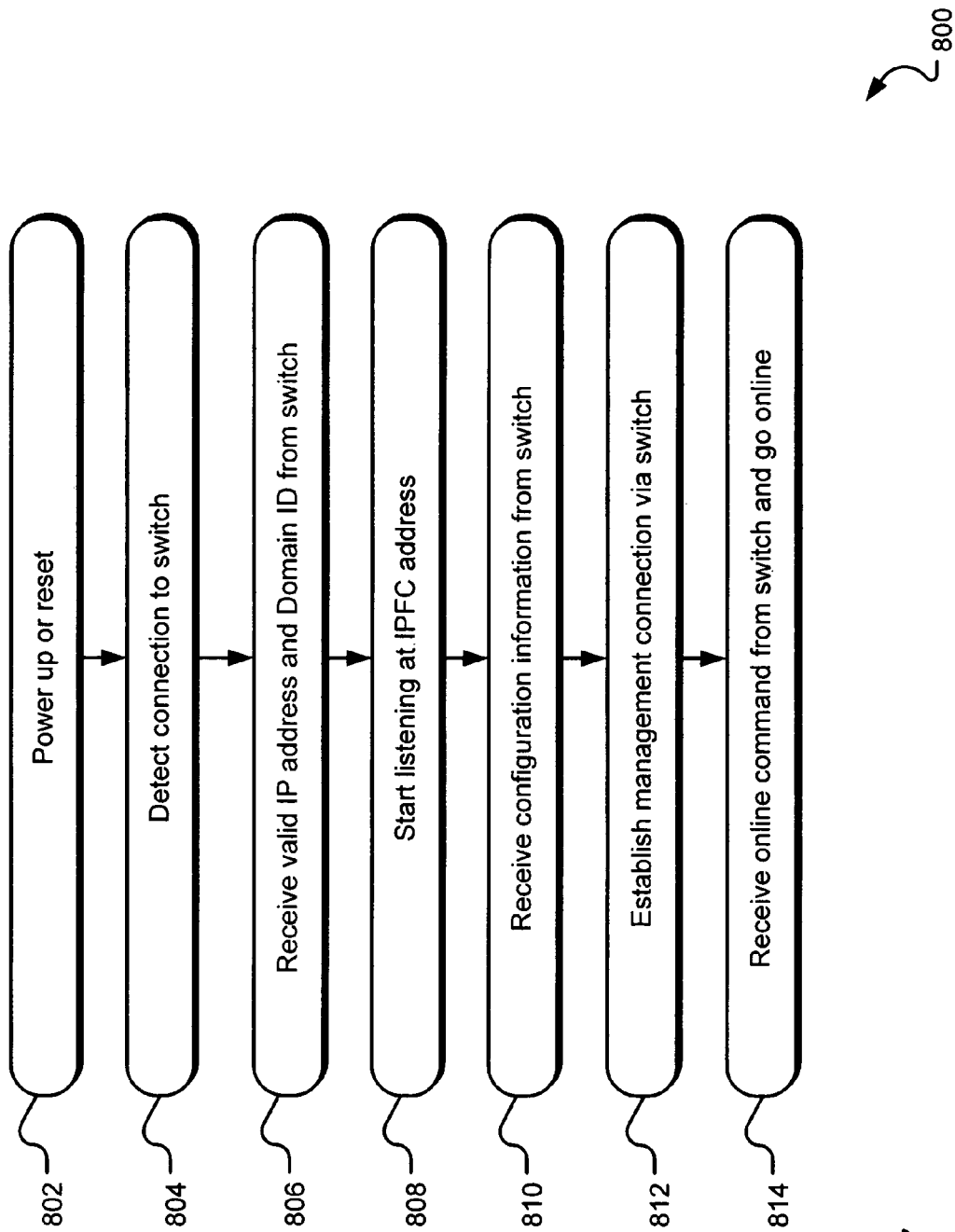




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Fig. 6

*Fig. 7*

*Fig. 8*

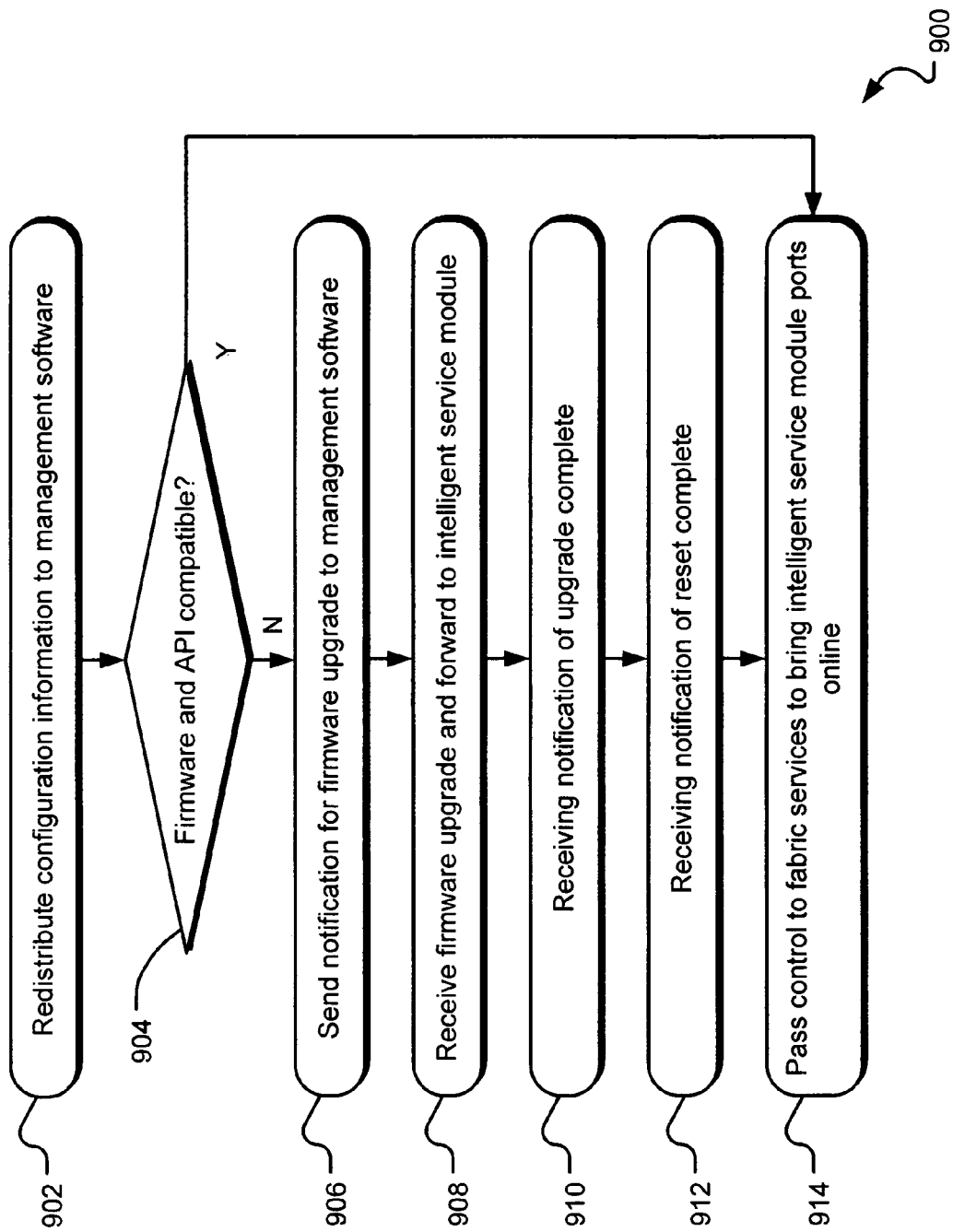


Fig. 9

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FEDERATED MANAGEMENT OF INTELLIGENT SERVICE MODULES

TECHNICAL FIELD

The invention relates generally to storage area networks, and more particularly to federated management of intelligent service modules in a storage area network.

BACKGROUND

A storage area network (SAN) may be implemented as a high-speed, special purpose network that interconnects different kinds of data storage devices with associated data servers on behalf of a large network of users. Typically, a storage area network includes high-performance switches as part of the overall network of computing resources for an enterprise. The storage area network is usually clustered in close geographical proximity to other computing resources, such as mainframe computers, but may also extend to remote locations for backup and archival storage using wide area network carrier technologies. Fibre Channel networking is typically used in SANs although other communications technologies may also be employed, including Ethernet and IP-based storage networking standards (e.g., iSCSI, FCIP (Fibre Channel over IP), etc.).

In one configuration, switches are assembled in a chassis using a selection of blade components of a SAN switch. Individual blade components are fitted into slots in the chassis and connected to a chassis backplane for interconnectivity. For example, line card blades, switch blades, and other blade components can be inserted into a chassis to provide a scalable and customizable storage network switch configuration. Typically, the blades are controlled by shared control processors (e.g., one active and one backup), powered by one or more shared power supplies through the backplane, and cooled by a shared set of cooling fan trays.

Fabric-based intelligent services, such as routing, virtualization, and distance services, may be added to a switch to enhance the performance, scalability, and features of the switch. For example, a wide area connectivity service blade can be inserted into an open slot in the chassis to provide fibre channel over IP bridging. In this fashion, the intelligent services can be managed as part of the switch.

However, adding such services as blades in a chassis presents significant limitations. A chassis has a limited number of slots, and a SAN administrator may not have an open slot in which to add an intelligent service blade. Even with an available slot, a service blade adds additional risk to the core switch, reducing the overall mean-time-between-failures (MTBF). Further, intelligent service blades tend to run hotter than core switch blades and therefore require placement in the better-cooled slots in the chassis. If such slots are already occupied by other blades, addition of a service blade can disrupt service as the other blades are moved around in the chassis. A chassis backplane also has power and signaling constraints that can restrict the scalability of a switch, particularly when an intelligent services blade is added to the chassis.

SUMMARY

Implementations described and claimed herein address the foregoing problems by providing intelligent services using intelligent service modules that can be cabled to a switch external to a chassis and yet be managed through the switch. In some implementations, such intelligent service modules

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may be managed as part of the switch's logical domain. Data and management communications between the intelligent service module and the core switch are provided through a "soft-backplane" implemented using in-band communications between the switch and the intelligent switch module rather than a hardwired backplane within the chassis. Each intelligent service module can be managed through the switch and/or within the same logical domain as the switch, such that a traditional physical Ethernet (i.e., out-of-band) connection between management software and each intelligent service module can be omitted. In this configuration, the switch can handle much of the management of the intelligent service module and otherwise forwards management communications received by the switch from the management software to the intelligent service module.

In some implementations, articles of manufacture are provided as computer program products. One implementation of a computer program product provides a non-transitory computer program storage medium readable by a computer system and encoding a computer program. Exemplary storage media may include without limitation magnetic and optical disks, EEPROMs, flash memory, RAM, and other storage devices.

Other implementations are also described and recited herein.

BRIEF DESCRIPTIONS OF THE DRAWINGS

FIG. 1 illustrates an exemplary computing and storage framework including a local area network (LAN) and a storage area network (SAN).

FIG. 2 illustrates exemplary multiple intelligent service modules connected to a chassis-based director-level switch.

FIG. 3 illustrates a rack of an exemplary modular SAN switch including switch modules and port modules, coupled to multiple intelligent service modules.

FIG. 4 illustrates an exemplary management network configuration including multiple switches and multiple intelligent service modules.

FIG. 5 illustrates exemplary component modules of an intelligent service module and a switch.

FIG. 6 illustrates an exemplary screenshot from a management software client.

FIG. 7 illustrates exemplary operations for initializing intelligent service module federated management, from the perspective of the switch.

FIG. 8 illustrates exemplary operations for initializing an intelligent service module, from the perspective of the intelligent service module.

FIG. 9 illustrates exemplary operation for bringing an intelligent service module online.

DETAILED DESCRIPTIONS

Federated management of intelligent service modules in a storage area network brings a combination of new management concepts and capabilities to traditional switching products. Intelligent service modules can be located external to a switch chassis and communicate with the switch components in the chassis via an external cable using a communications transport mechanism between the switch components and the intelligent service modules. In one implementation, for

example, IPFC (Internet Protocol over Fibre Channel) is employed as the transport mechanism between a switch and an intelligent service module. The intelligent service module is cabled to a switch through fibre channel ports in each device, such that the communications between the intelligent service module and the port module are “in-band” communications relative to the data communications of the switching network.

Each intelligent service module can be managed within the same logical domain as the switch, such that a traditional physical Ethernet (i.e., out-of-band) connection between management software and each intelligent service module can be omitted. In this configuration, the switch can handle much of the management of the intelligent service module and otherwise forwards management communications received by the switch from the management software to the intelligent service module.

Generally, a switching fabric involves a collection of interconnected switches that are capable of communicating among them. In contrast, a SAN can comprise one or more fabrics.

FIG. 1 illustrates an exemplary computing and storage framework 100 including a local area network (LAN) 102 and a storage area network (SAN) 104. Various application clients 106 are networked to application servers 108 and 109 via the LAN 102. Users can access applications resident on the application servers 108 and 109 through the application clients 106. The applications may depend on data (e.g., an email database) stored at one or more of the application data storage devices 110. Accordingly, the SAN 104 provides connectivity between the application servers 108 and 109 and the application data storage devices 110 to allow the applications to access the data they need to operate. It should be understood that a wide area network (WAN) may also be included on either side of the application servers 108 and 109 (i.e., either combined with the LAN 102 or combined with the SAN 104).

With the SAN 104, one or more switches 112 provide connectivity, routing and other SAN functionality. Some such switches 112 may be configured as a set of blade components inserted into a chassis or as rackable or stackable modules. The chassis has a back plane or mid-plane into which the various blade components, such as switching blades and control processor blades, may be inserted. Rackable or stackable modules may be interconnected using discrete connections, such as individual or bundled cabling.

In the illustration of FIG. 1, at least one switch 112 is coupled to at least one external intelligent service module. Rather than being inserted into an open slot in the switch chassis, the intelligent service module is connected to the switch 112 via an optical or wired cable. The intelligent service module can nevertheless be managed within the same logical domain as the switch without the need for a separate out-of-band connection. In addition, the intelligent service module can be “attached” or added to the switch without disrupting operation of the switch (e.g., to move blades or make chassis slots available).

FIG. 2 illustrates exemplary multiple intelligent service modules 200, 202, 204, and 206 connected to a chassis-based director-level switch 208. Fibre channel ports of each intelligent service module 200, 202, 204, and 206 are connected to fibre channel ports in the switch 208 by optical cabling 210 (although wired cabling, such as copper cabling, may alternatively be employed). Each illustrated intelligent service module has separate power supplies and cooling mechanisms, although individual intelligent service modules may share power supplies and/or cooling mechanisms in alternative configurations.

A management client 212 is connected to the switch 208 via an Ethernet connection. The management client 212 provides user control and monitoring of various aspects of the switch and attached devices, including without limitation, zoning, security, firmware, routing, addressing, etc. The management client 212 may identify the managed switch using a domain ID specific to the switch and, in a federated management configuration, shared with attached intelligent service modules. In addition, the management client 212 may identify the managed switch using a World Wide Name (WWN) or an IP address. In cases where a switch implements multiple virtual fabrics, the management client may use more than one domain ID in its communications with the switch. The management client 212 therefore can send a management request referencing the domain ID of the switch, an intelligent service module identifier, and a port identifier of an attached intelligent service module, and the switch will perform whatever portion of the requested management function it is capable of performing (if any) and forwards instructions to the intelligent service module possessing the referenced port for additional activity, if necessary.

Despite being external from the chassis, the intelligent service modules 200, 202, 204, and 206 can be managed within the same logical domain 214 as the switch 208. As discussed herein, each switch is attributed with a domain ID, each intelligent service module is attributed with a unique intelligent service module identifier within the logical domain 214 associated with the domain ID, and one or more ports of the intelligent service module are attributed with unique port identifier within the intelligent service module identifier. In this manner, the management client 212 can uniquely identify individual intelligent service modules and ports within the logical domain 214 of the switch and the switch can handle some portion of the management requests while forwarding certain management functions to the appropriate intelligent service module for processing, when necessary.

In the illustrated implementation, the intelligent service module 200 represents a virtualization intelligent service module (VSM) that provides Layer 4 SCSI/block storage services. The VSM 200 provides virtualization services and flexible switch connectivity. The VSM 200 has fibre channel ports, which can be connected by cabling to the switch 208 to provide private uplink connection. One of the uplinks can be designated as an active path and another of the uplinks can be designated as a standby path. Upon failover, the standby path is promoted to the active path, and another uplink is designated as the new standby path. Alternatively, communications can be spread among all available links.

Each virtual device (e.g., a virtual target or virtual initiator of the virtualization engine) within the VSM 200 logs into the switch 208 indirectly using a specified protocol. Each of these virtual devices also logs in with NPIV (N_port ID Virtualization), which provides a fibre channel facility for sharing a single physical port among multiple port IDs. In this manner, multiple virtual initiators are capable of sharing the port, with each initiator having its own port ID. Accordingly, the VSM 200 appears to the switch 208 as an extended end device, rather than another switch. Therefore, the VSM 200 does not consume another domain ID; it falls within the logical domain of the switch 208.

Another intelligent service module 202 in the illustration of FIG. 2 represents a routing intelligent service module (RSM) that provides Layer 3 SAN routing services. The RSM 202 provides inter-fabric routing between physical and virtual fabrics within the SAN. Yet another intelligent service module 204 in FIG. 2 represents a WAN intelligent service

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module (WSM) that can provide wide area connectivity, including iFCP or FCIP bridging, FICON tunneling, and streaming, such as fast write, compression, encryption, etc. Yet another intelligent service module **206** in FIG. 2 represents an aggregation intelligent service module (ASM) that aggregates end devices (e.g., host initiators or storage targets) to the attached switch **208**, thereby simplifying the core-edge topology into a collapsed core that is a logical part of the switch **208**.

FIG. 3 illustrates a rack **300** of an exemplary modular SAN switch **302** including switch modules **304** and port modules **306**, coupled to intelligent service modules **308**. The illustration shows an alternative configuration in which the blade-and-chassis switch is replaced with multiple port modules and switch modules, which can be connected via cabling to one or more intelligent service modules. In one implementation, the intelligent service modules **308** connect to the switch **302** via cabling (not shown) to fibre channel ports on the front of the port modules **306**. Alternatively, the intelligent service modules **308** can connect via cabling (not shown) to back-plane extender ports in the back of the intelligent switch modules **308**. In either case, the intelligent service modules **308** are managed through the switch **302**, and in some implementations, managed within a logical domain of the switch **302**.

FIG. 4 illustrates an exemplary management network configuration **400** including multiple switches **402** and **404** and multiple intelligent service modules **406**, **408**, and **410**. In one configuration, a switch and an intelligent service module are connected by one or more fibre channel cables attached to fibre channel ports in each module. Management traffic, such as from a management client **412** to the switch **402**, travels through an Ethernet network **414** to a management Ethernet port in the switch **402**. In the event the management traffic is forwarded or otherwise sent to the intelligent service module **406**, for example, the traffic is transmitted across the fibre channel connection between the switch **402** and the intelligent service module **406** via a fibre channel transport mechanism. The transport mechanism employed in the illustrated configuration is IPFC (IP over Fibre Channel), for which IP addresses (e.g., 172.16.20.25 and 172.16.20.26) are assigned to each intelligent service module **406** and **408** or other device within the federated management configuration, such as the switch **402** and the intelligent service module **410**. (Hereafter, the IP addresses for intelligent service modules on the fibre channel connections are referred to as IPFC addresses to distinguish them from Ethernet IP addresses of various devices (e.g., 172.16.20.20 and 172.16.20.21).) The management client **412** can use the IPFC addresses to route management traffic (e.g., IP packet forwarding) through the switch **402** to the appropriate intelligent service modules attached to the switch **402**. Alternatively, the management client **412** can route management traffic directed at an intelligent service

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module to the switch **402** by specifying the domain ID, an intelligent service module identifier, and a port identifier, if necessary.

In one implementation, the management software **412** may also direct management traffic through the switch **402** to the switch **404** and the intelligent service module **410**. In this manner, a single management Ethernet connection to a single switch (**402**) can be used to manage devices, such as intelligent service modules and switches, throughout the storage network. For example, the management software **412** can specify the domain ID1 (of the switch **402**), a switch identifier (e.g., domain ID2) of the switch **404**, an intelligent service module identifier of the intelligent service module **410**, and a port identifier of a port on the intelligent service module **410**. In this implementation, the switch **402** interprets the management request as destined for another logical domain and forwards the request to the switch **404** according to the domain ID2. Thereafter, the switch **404** determines the IPFC address of the appropriate intelligent service module and forwards the request to the intelligent service module **410** via the fibre channel connection. In alternative implementations, the management software may additionally or alternatively address a switch using an IP address or WWN.

The exemplary IPFC implementation for communicating between switches and intelligent service modules allows management traffic from the management software to travel through the switch to the appropriate intelligent service modules using in-band communications while requiring minimal processing by the switch. In one implementation, management Ethernet packets are sent to the switch's MAC address using a proxy-ARP (address resolution protocol) function on the switch (e.g., included in Ethernet Interface/Network Management Services module **516** of FIG. 5). When the management software **412** issues an ARP request for an intelligent service module IPFC address, the switch answers with its own MAC address. Therefore, for intelligent service modules within federated management of the switch **402**, the ARP table within the management software **412** contains the MAC address of the switch **402**. Accordingly, when the management software **412** sends out management requests to such an intelligent service module, the packets are sent to the switch **402**.

When the switch **402** receives a management request specifying an intelligent service module, the switch **402** examines the IPFC address in the request and recognizes it as not matching its own IP address. Therefore, the switch **402** looks up another destination address on its fibre channel connection to which to send the request via IPFC, typically using a local federated management address table that is similar to an ARP table. An exemplary local federated management address (FMA) table is shown below for an IP address of a switch, an intelligent service module, with reference to the IP/IPFC addresses in FIG. 4 (Note: In the example given in Table 1, end devices (e.g., targets or initiators) are referenced by WWPNs.):

TABLE 1

| Exemplary local federated management address (FMA) table | | | | |
|--|-------------|-----------|---|-------------|
| Example IP/IPFC Address | Device Type | WWNN/WWPN | Domain_ID | Port Number |
| 172.16.20.19 | Switch | WWNN | Domain controller of destination Switch (e.g., Domain ID2). | N/A |

TABLE 1-continued

| Exemplary local federated management address (FMA) table | | | | |
|--|--|-----------|---|---|
| Example IP/IPFC Address | Device Type | WWNN/WWPN | Domain_ID | Port Number |
| 172.16.20.25 | Locally-attached Intelligent service module | WWNN | Domain controller of attached switch (e.g., Domain ID1) | Port number of switch at which the intelligent service module attaches to switch |
| 172.16.20.27 | Remotely- attached Intelligent service module | WWNN | Domain controller of attached switch (e.g., Domain ID2) | N/A |
| | End Device | WWPN | Domain ID for the end device | N/A |

It should also be understood that SAN devices may also be referenced by other unique identifiers, including Fibre Channel addresses (e.g., FCIDs), IPFC addresses, and iSCSI addresses.

An IPFC module on the switch **402** wraps the request in an IPFC frame in order to forward the request in-band across a fibre channel connection. When the switch **402** looks up another destination address in the FMA table, it first reads the Type field in the table row associated with the IP/IPFC address in the request to determine how to route the request. If the Type designates another switch, the IPFC-wrapped request is sent to the domain controller for the switch associated with the received IPFC address using the WWNN for the destination switch. For an intelligent service module attached to the switch **402**, the switch **402** sends the IPFC-wrapped request to the fabric controller address FFFFD using the port number for the specified intelligent service module. For an intelligent service module not attached to the switch **402** (e.g., switch **410**), the IPFC-wrapped request is sent to the domain controller of the intermediary switch **404** using the WWNN for that switch. The switch **404** is then responsible for forwarding the request to the intelligent service module **410** using its own local FMA table. For an end device, the IPFC frame is forwarded to the end device using the WWPN and the Domain ID.

FIG. **5** illustrates exemplary component modules of an intelligent service module **500** and a switch **502**. The management software **514** and CLI (command line interface) client **512** provide interfaces through which a user can manage the devices in the storage network. Typically, the computer executing the management software **514** may be connected to the switch **502** by an Ethernet connection, and the computer executing the CLI client **512** may be connected to the switch **502** by a serial connection.

The switch **502** and the intelligent service module **500** each include one or more processors controlled by firmware, which embodies instructions for executing the various modules illustrated in FIG. **5**. At power-up, components of the firmware are read from persistent storage (e.g., flash memory) on the device and executed by the processor. Individual modules are illustrated to describe an exemplary functional division in one implementation of a switch and one implementa-

tion of an intelligent service module. It should be understood, however, that alternative functional divisions may be employed, and some functions may be implemented in circuitry.

Federated management modules **504** and **506** in the intelligent service module **500** and the switch **502** respectively are similar, although the two federated management modules **504** and **506** may have different functionality. In one implementation, the functionality of the federated management modules **504** and **506** is allocated as follows:

Federated Management Module for an Intelligent Service Module

Maintains the state of the intelligent service module

Handles communications of intelligent service module configuration data with the switch

Forwards asynchronous data to the switch

Federated Management Module for a Switch

Maintains state for each intelligent service module connected through federated management by the switch

Handles initialization of intelligent service module IPFC addresses

Handles verification of federated management firmware levels

Handles communications of intelligent service module configuration data with the intelligent service module

Receives asynchronous data from the intelligent service module

The federated management modules **504** and **506** implement one or more APIs (application programming interfaces). One exemplary API is termed the federated management API, which provides an interface for management subsystems (e.g., firmware services) to access the intelligent service module **500** from the switch **502**. In one implementation, the federated management API functions are written in C Programming Language source code for platform independence. Each of the functions creates XML commands corresponding to the API type and supplied parameters. Such XML commands are sent to the federated management module on the opposite side of the switch/server-module connection via IPFC. The receiving federated management module parses the XML command and calls the appropriate environment API function. Exemplary commands, functions, and formats include:

TABLE 2

| Exemplary federated management API calls and XML format | | | |
|---|---------------|---|---|
| Command Schema | Function Name | Description | Example |
| Call | get - | Retrieves values from an intelligent service module | <pre> <call name="function_name" id=idNum" optionalAttr(s)=optionalValues(s)"> P₁,P₂,P₃,...P_N </call> OR <call name="function_name" id=idNum" optionalAttr(s)=optionalValues(s)"> <tag₀>...</tag₀> <tag₁>...</tag₁> ... </call> </pre> <p>where idNum is a unique sequence number to align requests and responses, optionalAttr(s) specifies optional calling parameter statements, p_n specifies optional calling parameters, and tag_x specifies optional internal tag structures - (issued by switch).</p> |
| | set - | Set values of an intelligent service module | |
| | notify - | Used to communicate asynchronous changes in device | |
| Return | set - | Returns success or error in response to a "call set" function | <pre> <return name="function_name" id=idNum" error="errornum"> P₁,P₂,P₃,...P_N </return> OR <return name="function_name" id=idNum" error="errornum"> <tag₀>...</tag₀> <tag₁>...</tag₁> ... </return> </pre> <p>where idNum is a unique sequence number to align requests and responses, error specifies an integer error number (0 equals success), p_n specifies optional calling parameters, and tag_x specifies optional internal tag structures — (issued by intelligent service module).</p> |
| | get - | Retrieves values from a switch | |
| Notify | set - | Set values of a switch | <pre> <notify name="function_name" optionalAttr(s)= optionalValues(s)"> P₁,P₂,P₃,...P_N </notify> </pre> <p>where optionalAttr(s) specifies optional calling parameter statements and p_n specifies optional calling parameters - (issued by intelligent service module)</p> |
| | get - | Retrieves values from a switch | |

Another exemplary API is termed a host environment API, through which the federated management modules **504** and **506** accesses persistent storage, provides notification, and receives status information. The host environment API functions provide wrappers or translation functions between the management subsystems and the federation management modules.

One exemplary function performed by the federated management modules **504** and **506** is the communication of intelligent service module configuration data. Initially, the federated management module **506** in the switch **502** initializes generic configuration information pertaining to the intelligent service module **500**, stores it in persistent storage **508** and then forwards the configuration information to the intelligent service module **500**. The federated management module **504** in the switch module **500** receives the generic configuration information from the switch, stores it in persistent storage **510**, and when appropriate, supplements the configuration information in the persistent storage **510** with service-module-specific configuration information (e.g., configuration information specific to the type or instance of the intelligent service module **500**). The configuration data (both generic and service-module-specific) is mirrored on both the intelligent service module **500** and the switch **502** to provide a backup for each device.

One example of an API data flow includes a command line interface (CLI) command from the CLI client **512** through the switch to configure a port parameter physically belonging to the intelligent service module **500**. The data flow starts with entry of a command through the interface of the CLI client. The command data is sent via a serial interface through the Ethernet interface/network management service **516** to the federated management module **506** in the switch **502**. The federated management module **506** first stores the command data locally in the persistent storage **508** via the data storage engine **518** and then determines that the port number provided in the command data applies to the attached intelligent service module **500**. Alternatively, the federated management module **506** may not store the command data locally in the persistent storage **508** (e.g., when the command data is intended only for an attached intelligent service module).

Having identified the destination intelligent service module **500**, the federated management module **506** calls a federated management API function that creates an XML string with parameters and sends it to the destination intelligent service module **500** via IPFC through the fibre channel interface **520**. The XML string is received by the intelligent service module **500** through the fibre channel interface **522** and the Ethernet interface/network management service **524** to the federated management module **504** in the intelligent ser-

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vice module **500**. The federated management module **504** then calls the appropriate host environment API function to effect the configuration change to port parameter of the intelligent service module **500**. The configuration change is written to the persistent storage **510** via a data storage engine **526**, which returns a success or failure return code. Assuming the configuration change at the intelligent service module is successful, a successful return code is returned to the switch **502**, which makes a similar change to the configuration information stored in the switch **502** in order to keep the configuration information in the switch **502** synchronized (i.e., “mirrored”) with the configuration information in the intelligent service module **500**.

In another example, a port property change occurs on the intelligent service module **500**, which issues an asynchronous notification to the switch **502**. A status subsystem in the intelligent service module **500** detects the port property change and calls the federated management API function to create an XML string with parameters as a notification of the change. The federated management module **504** transfers the notification of the change to the switch **502** via IPFC and the fibre channel interfaces of the intelligent service module **500** and the switch **502**. On the switch side of the communication, the federated management module **506** parses the XML string and calls the appropriate host environment API function to update the status information in the switch **502**.

FIG. 6 illustrates an exemplary screenshot **600** from a management software client. The screenshot **600** displays a graphic of a switch **602** in a chassis that includes line card blades, control processors blades, power supplies, fan trays, etc. Although not shown in the screenshot graphics, switch **602** and the intelligent service modules **604**, **606**, **608**, **610**, and **612** are connected via fibre channel cables between the front ports of the intelligent service modules and the front ports of the line cards in the switch chassis. The management software client executes on a workstation that is coupled to a management Ethernet port of the switch **602** and, therefore, controls functionality of the switch **602**, including configuration, zoning, security, monitoring of the switch. Furthermore, in light of the federated management architecture, the management software client can also control functionality of properly-configured intelligent service modules attached to the switch **602**, such as virtualization intelligent service modules (VSMs) **604** and **612**, routing intelligent service module (RSM) **610**, and aggregation intelligent service modules (ASMs) **606** and **608**.

FIG. 7 illustrates exemplary operations **700** for initializing intelligent service module federated management, from the perspective of the switch. A detecting operation **702** detects connection of an intelligent service module via a fibre channel port (or possibly an extender port). In one implementation, the connection is detected by a fabric services component of the switch, which notifies the federated management module that an intelligent service module has been connected.

In response to detecting an intelligent service module connection, a link operation **704** initializes a federated management link with the intelligent service module. The federated management module collects a World Wide Node Name (WWNN) from the intelligent service module and collects a range of area IDs for the intelligent service module, a domain ID to be assigned to the intelligent service module, and an IPFC address for the intelligent service module from the user or configuration data through the management software. Alternatively, a set of available values may be pre-defined in

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the management software or switch and dynamically allocated when an intelligent service module is connected to the switch.

In a querying operation **706**, the federated management module then transmits and assigns the IPFC address to the intelligent service module, and on the basis of that IPFC address, queries the intelligent service module for its type (e.g., VSM, ASM, RSM, etc.), its firmware version (and corresponding API version), and the number of logical ports requested by the intelligent service module. In a configuration operation **708**, the federated management module locally stores the collected information and other default values attributable to the intelligent service module as configuration information for the intelligent service module.

In a transmission operation **710**, the switch presents a portion of the configuration information to a management software client or CLI client and awaits a response from a user. An exemplary set of configuration information parameters sent to the user may include the intelligent service module type, the IPFC address, the firmware version, the number of requested logical ports, the WWNN, the range of area IDs, and the domain ID to be assigned to the intelligent service module.

In a receiving operation **712**, the switch receives the response set of configuration information from the user, via a management interface. This set of configuration information may have been changed by the user. In addition, the response from the user includes an acceptance or rejection of the intelligent service module into the federated management configuration. (In some circumstances, the user may wish to manage the intelligent service module independently of the switch.) If there are any changes to the configuration information, the federated management module updates the switch's local storage of the configuration information.

A transmission operation **714** forwards the configuration information to the intelligent service module, including logical port assignments, data inherited from the switch, port configuration information, etc. In one implementation, transmission of the domain ID and area ID range to the intelligent service module is accomplished using a separate FC-SW exchange, although in an alternative implementation, the transmission operation **714** may forward all of the configuration information together. (FC-SW represents a switch interoperability standard using in-band communications).

In one implementation, the intelligent service modules are organized using a numbering structure, which uniquely indexes individual intelligent service modules, physical ports, port areas, and logical ports. Each intelligent service module is designated with an intelligent service module identifier or index, which may be configured by a user. The intelligent service module identifier is unique for each intelligent service module attached to the same switch. In one convention, the switch is assumed to be index 0, and any attached intelligent service module is numbered index 1 through N, where N is the limit of intelligent service modules that may be attached to a single director. Each intelligent service module also has a service-module-context port number, referred to as a port locator. As such, a port of any intelligent service module can be referenced by a value pair including the intelligent service module identifier and the port locator.

In addition, each intelligent service module port can be referenced by an integer number within the context of the switch. The switch-context identifier is generally dependent on the type and specifications of the switch.

In one implementation, the switch firmware presents both service-module-context descriptions and switch-context descriptions to the management software. Accordingly, an

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exemplary data structure for identifying a service-module port using 32-bits is employed:

```

struct PORT_COMPOSITE_DESCRIPTION {
    UNS16    port_integer;
    byte     sm_index;
    byte     port_locator;
}

```

It should be understood, however, that other data structures may be employed, and either the port_integer value or the sm_index:port_locator value may be used individually as needed. For example, management software may include a look-up table that maps port_integer values to sm_index:port_locator values and/or vice versa.

The intelligent service module mirrors the configuration information in its own local storage, gathers service-module-specific information, updates the configuration information in local storage with this service-module-specific information, and returns the service-module-specific information to the switch. In receiving operation 716, the switch receives and stores the service-module-specific information from the intelligent service module, updating its local storage with the new information. To this point, the intelligent service module remains offline.

FIG. 8 illustrates exemplary operations 800 for initializing an intelligent service module, from the perspective of the intelligent service module. A power operation 802 powers up or resets the intelligent service module. After the intelligent service module is operational, a detection operation 804 detects a connection to a switch and makes itself available to receive data via the connection.

An address operation 806 receives the IPFC address and domain ID from the switch, which are also stored in the local storage of the intelligent service module. A listening operation 808 sets a network management intelligent service module to listen for messages on the appropriate TCP port capable of servicing the IPFC address.

If the user indicates that the intelligent service module is to be managed through the switch via federated management, a configuration operation 810 receives generic configuration information from the switch, which may include user-specified parameters, and stores the configuration information in the local storage of the intelligent service module. The configuration operation 810 also gathers service-module-specific configuration information from the intelligent service module's components and updates the locally stored configuration information with the service-module-specific configuration information. The updated configuration information can be sent back to the switch to ensure that the switch mirrors the updated information.

In a connection operation 812, the management software client or CLI interface establishes a management connection with the intelligent service module through the switch. In one implementation, this connection is accomplished through a fibre channel cable via the switch. In an alternative implementation, this connection is accomplished through a back-plane extender port and cabling to a switch module. Management requests to the intelligent service module are forwarded from the switch in accordance with the addressing schemes described herein or some other applicable addressing scheme. When, in receiving operation 814, the intelligent service module receives an "online" command from the fabric services of the switch, the intelligent service module begins providing its intelligent service (e.g., routing, security, aggregation, virtualization, etc.) to the storage network.

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FIG. 9 illustrates exemplary operation 900 for bringing an intelligent service module online. A distribution operation 902 redistributes information about the switch and attached intelligent service modules, emulating a new discovery operation. In this manner, the management software has updated information describing the switch in its new incarnation, which includes one or more new intelligent service modules (or alternatively, some change to the set of attached intelligent service modules).

In compatibility operation 904, the switch compares the firmware and API versions provided by each intelligent service module and determines whether a firmware update is required. In one implementation, the switch firmware maintains compatibility information in the form of a configuration file. The file specifies which firmware and API versions on the service modules are compatible with the current switch firmware. Alternatively, a database of compatibility information can be maintained and accessed by the switch firmware.

If the firmware versions and API versions are not compatible between the switch's firmware and the intelligent service module's firmware, an upgrade request operation 906 requests an intelligent service module firmware upgrade from the management software client, which alerts the user that an upgrade is needed. If the user approves, an upgrade operation 908 sends the upgraded firmware to the intelligent service module via the switch and causes it to be installed in the intelligent service module. The intelligent service module notifies the switch when the installation is complete (notification operation 910), resets, and then notifies the switch that the reset is complete (notification operation 912).

The embodiments of the invention described herein are implemented as logical steps in one or more computer systems. The logical operations of the present invention are implemented (1) as a sequence of processor-implemented steps executing in one or more computer systems and (2) as interconnected machine or circuit modules within one or more computer systems. The implementation is a matter of choice, dependent on the performance requirements of the computer system implementing the invention. Accordingly, the logical operations making up the embodiments of the invention described herein are referred to variously as operations, steps, objects, or modules. Furthermore, it should be understood that logical operations may be performed in any order, unless explicitly claimed otherwise or a specific order is inherently necessitated by the claim language.

The above specification, examples and data provide a complete description of the structure and use of exemplary embodiments of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended. Furthermore, structural features of the different embodiments may be combined in yet another embodiment without departing from the recited claims.

What is claimed is:

1. A method comprising:

receiving an intelligent service module management request at a switch, the intelligent service module management request being associated with an intelligent service module; and

forwarding the intelligent service module management request to the intelligent service module via at least one communication connection;

wherein the intelligent service module is configured to provide fabric-based intelligent services.

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2. The method of claim 1 further comprising:
receiving a response to the intelligent service module management request from the intelligent service module via the at least one communication connection.
3. The method of claim 1 further comprising:
receiving at the switch an address resolution request from a management client, the request specifying an address assigned to the intelligent service module; and
returning a physical address of the switch in response to the receiving operation.
4. The method of claim 3 wherein the address assigned to the intelligent service module includes an IPFC address.
5. The method of claim 3 wherein the address assigned to the intelligent service module includes a Fibre Channel address.
6. The method of claim 3 wherein the address assigned to the intelligent service module includes an IP address.
7. The method of claim 3 wherein the intelligent service module management request is addressed to the physical address of the switch and includes the address assigned to the intelligent service module.
8. The method of claim 1 wherein the intelligent service module management request includes an address assigned to the intelligent service module and further comprising:
determining a port number of the switch associated with the address included in the intelligent service module management request, wherein the forwarding operation forwards the intelligent service module management request through a switch port designated by the port number.
9. The method of claim 1 wherein the switch is a first switch, the intelligent service module management request includes an address of the intelligent service module, the intelligent service module is attached to a second switch, the second switch is coupled to the first switch, and further comprising:
determining a unique identifier of the second switch associated with the address included in the intelligent service module management request, wherein the forwarding operation forwards the intelligent service module management request through the at least one communication connection according to the unique identifier of the second switch.
10. The method of claim 9 wherein the unique identifier of the second switch is a world wide node name.
11. The method of claim 1 further comprising:
receiving a switch management request at the switch, the switch management request being associated with another switch that is coupled to the switch;
determining a unique identifier of the other switch associated with the address included in the switch management request; and
forwarding the switch management request to the other switch via the at least one communication connection according to the unique identifier.
12. The method of claim 11 wherein the unique identifier of the other switch is a world wide node name.
13. The method of claim 1 further comprising:
receiving a device management request at the switch, the management request being associated with an end device that is coupled to the switch;
determining a unique identifier of the end device associated with the address included in the device management request; and
forwarding the device management request to the device via the at least one communication connection according to the unique identifier.

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14. The method of claim 13 wherein the unique identifier of the end device is a world wide port name.
15. The method of claim 1 wherein the forwarding operation comprises:
translating the intelligent service module management request into an XML command before transmitting the intelligent service module management request over the at least one communication connection.
16. The method of claim 1 wherein the receiving operation comprises:
receiving the intelligent service module management request at the switch via a management client coupled to the switch via an Ethernet connection.
17. The method of claim 1 wherein the receiving operation comprises:
receiving the intelligent service module management request at the switch via a management client coupled to the switch via a serial connection.
18. A network switch comprising:
a first port for communicative coupling to a management client;
a second port for communicative coupling to an intelligent service module;
circuitry configured to forward an intelligent service module management request from the first port to the second port, wherein the intelligent service module management request identifies the network switch and an intelligent service module, and wherein the intelligent service module is configured to provide fabric-based intelligent services.
19. The network switch of claim 18 further comprising:
a network management services module in the switch configured to receive an address resolution request from a management client, the request specifying an address assigned to the intelligent service module, and to return a physical address of the switch in response to the address resolution request.
20. The network switch of claim 19 wherein the address assigned to the intelligent service module includes an IPFC address.
21. The network switch of claim 19 wherein the address assigned to the intelligent service module includes a Fibre Channel address.
22. The network switch of claim 19 wherein the address assigned to the intelligent service module includes an IP address.
23. The network switch of claim 19 wherein the intelligent service module management request is addressed to the physical address of the switch and includes the address assigned to the intelligent service module.
24. The network switch of claim 18 wherein the intelligent service module management request includes an address assigned to the intelligent service module and further comprising:
an address data structure that associates the address with a port number of the switch, wherein the circuitry is configured to examine address data structure to determine the port number of the switch associated with the address included in the intelligent service module management request and a communications interface is configured to forward the intelligent service module management request through a switch port designated by the port number.
25. The network switch of claim 18 wherein the circuitry is configured to forward the intelligent service module management request by translating the intelligent service module management request into an XML command before transmit-

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ting the intelligent service module management request over the at least one communication connection.

26. A method comprising:

detecting connection of an intelligent service module to a switch, wherein the switch is associated with a logical domain;

assigning an address to the intelligent service module, the address being unique within the logical domain associated with the switch;

associating the address with a physical address of the switch; and

communicating the address and associated physical address to a management client coupled to the switch; wherein the intelligent service module is configured to provide fabric-based intelligent services.

27. The method of claim **26** wherein the address includes an IPFC address.

28. The method of claim **26** wherein the address includes a Fibre Channel address.

29. The method of claim **26** wherein the address includes an IP address.

30. The method of claim **26** further comprising:

receiving at the switch an intelligent service module management request from the management client, the intelligent service module management request including the physical address of the switch and the address assigned to the intelligent service module; and

forwarding the intelligent service module management request to the intelligent service module.

31. The method of claim **26** wherein the intelligent service module and the switch are coupled by a communication connection and the forwarding operation comprises:

transmitting the intelligent service module management request to the intelligent service module via the communication connection.

32. The method of claim **26** further comprising:

detecting whether an API supported by the intelligent service module is compatible with an API supported by the switch.

33. The method of claim **32** further comprising:

updating the API supported by the intelligent service module if the detecting operation determines that the API supported by the intelligent service module is not compatible with the API supported by the switch.

34. The method of claim **26** further comprising:

detecting whether firmware executed by the intelligent service module is compatible with firmware executed by the switch.

35. The method of claim **34** further comprising:

updating the firmware executed by the intelligent service module if the detecting operation determines that the firmware executed by the intelligent service module is not compatible with the firmware executed by the switch.

36. A switch comprising:

circuitry configured to assign an address to an intelligent service module, the address being unique within a logical domain associated with the switch, the circuitry being further configured to associate the address with a physical address of the switch; and

an Ethernet interface coupled to the circuitry and being configured to communicate the address and associated physical address to a management client;

wherein the intelligent service module is configured to provide fabric-based intelligent services.

37. The switch of claim **36** wherein the address includes an IPFC address.

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38. The switch of claim **36** wherein the address includes a Fibre Channel address.

39. The switch of claim **36** wherein the address includes an IP address.

40. The switch of claim **36** wherein the intelligent service module and the switch are coupled by one or more communication connections.

41. A method comprising:

detecting connection of an intelligent service module to a switch, wherein the switch is associated with a logical domain;

providing an address from the switch, the address being unique within the logical domain; and

forwarding an intelligent service module management request via the address from the switch to the intelligent service module, the intelligent service module management request being associated with the intelligent service module;

wherein the intelligent service module is configured to provide fabric-based intelligent services.

42. The method of claim **41** wherein the address includes an IPFC address.

43. The method of claim **41** wherein the address includes a Fibre Channel address.

44. The method of claim **41** wherein the address includes an IP address.

45. The method of claim **41** wherein the intelligent service module and the switch are coupled by a communication connection and the operation of receiving an intelligent service module management request comprises:

receiving the intelligent service module management request from the switch via the communication connection.

46. An intelligent service module comprising:

an Ethernet interface configured to be assigned an address by the switch, the address being unique within a logical domain associated with the switch, and

circuitry configured to process an intelligent service module management request sent to the address from the switch;

wherein the intelligent service module is configured to provide fabric-based intelligent services.

47. The intelligent service module of claim **46** wherein the address includes an IPFC address.

48. The intelligent service module of claim **46** wherein the address includes a Fibre Channel address.

49. The intelligent service module of claim **46** wherein the address includes an IP address.

50. The intelligent service module of claim **46** wherein the intelligent service module is coupled to the switch by one or more communication connections.

51. A non-transitory computer-readable medium storing computer-executable instructions for performing a computer process implementing a method comprising:

receiving an intelligent service module management request at a switch, the intelligent service module management request being associated with an intelligent service module; and

forwarding the intelligent service module management request from the switch to the intelligent service module via at least one communication connection;

wherein the intelligent service module is configured to provide fabric-based intelligent services.

52. A non-transitory computer-readable medium storing computer-executable instructions for performing a computer process implementing a method comprising:

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detecting connection of an intelligent service module to a switch, wherein the switch is associated with a logical domain, wherein the intelligent service module is configured to provide fabric-based intelligent services;

assigning an address to the intelligent service module, the address being unique within the logical domain associated with the switch;

associating the address with a physical address of the switch; and

communicating the address and associated physical address to a management client coupled to the switch.

53. A non-transitory computer-readable medium storing computer-executable instructions for performing a computer process implementing a method comprising:

detecting connection of an intelligent service module to a switch, wherein the switch is associated with a logical domain and wherein the intelligent service module is configured to provide fabric-based intelligent services;

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providing an address from the switch, the address being unique within the logical domain; and

forwarding an intelligent service module management request via the address from the switch.

54. A network switch comprising:

a first port for communicative coupling to a management client;

a second port for communicative coupling to an intelligent service module, wherein the intelligent service module is configured to provide fabric-based intelligent services;

federated management means for forwarding an intelligent service module management request from the first port to the second port, wherein the intelligent service module management request identifies the network switch and an intelligent service module.

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